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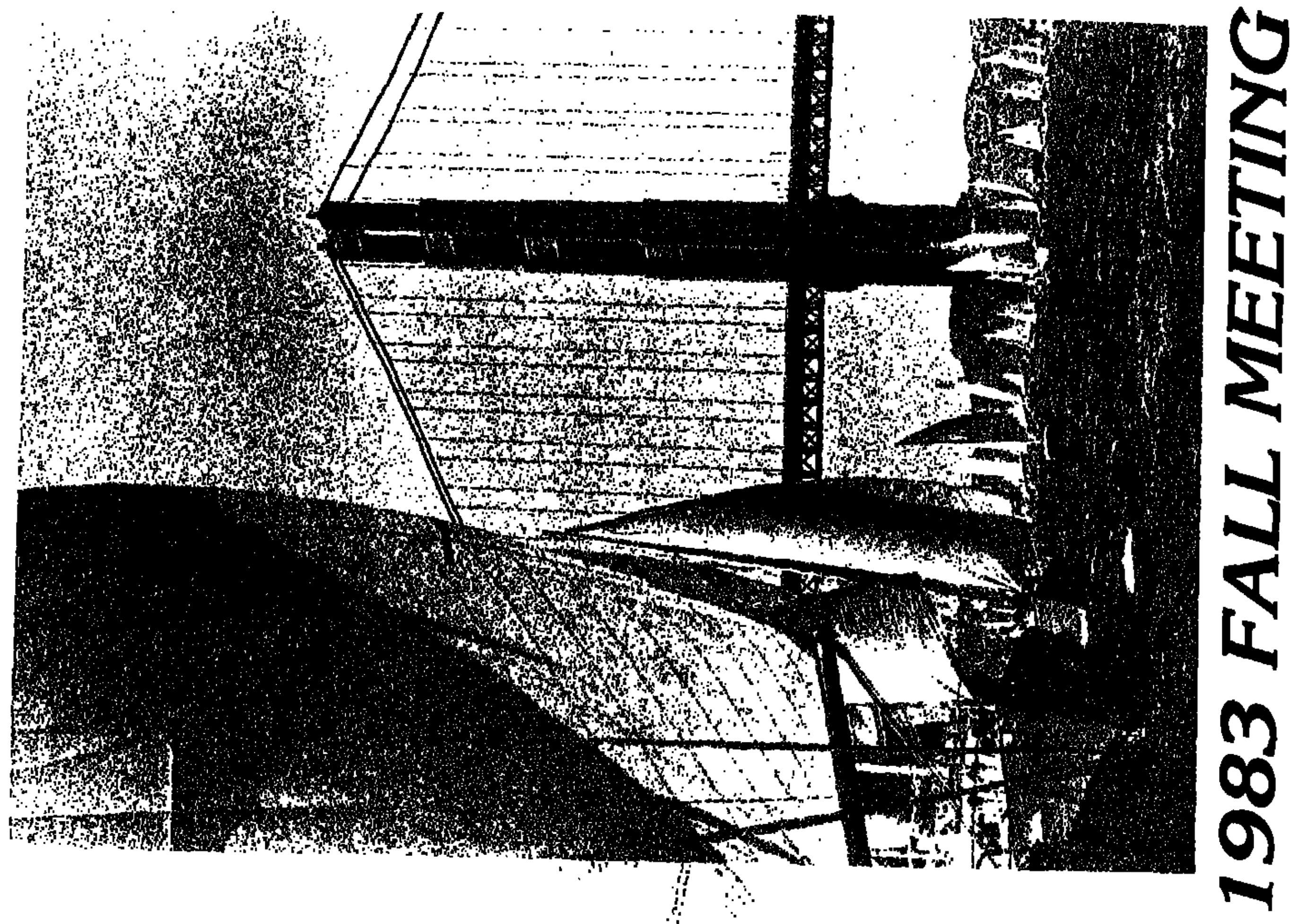

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GRM: Observing the Terrestrial Gravity and Magnetic Fields in the 1990's

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Beginning with the earliest days of space exploration, satellites have been used to chart the gravity and magnetic fields of the earth. As a continuation of these studies NASA is proposing to launch a new geopotential fields exploration system called the Geopotential Research Mission (GRM). Two spacecraft will be placed in a circular polar orbit at 160 km altitude. Distances between these satellites will vary from 100 to 600 km. Both scalar and vector magnetic fields will be measured by magnetometers mounted on a boom positioned in the forward direction on the lead satellite. Gravity data will be computed from the measured change in distance between the two spacecraft. This quantity, called the range-rate, will be determined from the varying frequency (Doppler shift) between transmitter and receiver on each satellite. Expected accuracies (at the one sigma level) are: gravity field, 1×10^{-5} m s^{-2} (1 milliGal), 6 cm geoid height; magnetics, scalar field 2 nT, vector to 20 arc seconds (96 microradians), both resolved to less than 100 km.

With these more accurate and higher resolution data we will be able to investigate the earth's structure from the crust (with the shorter wavelength gravity and magnetic anomalies) through the mantle (from the intermediate wavelength gravity field) and into the core (using the longer wavelength gravity and magnetic fields).

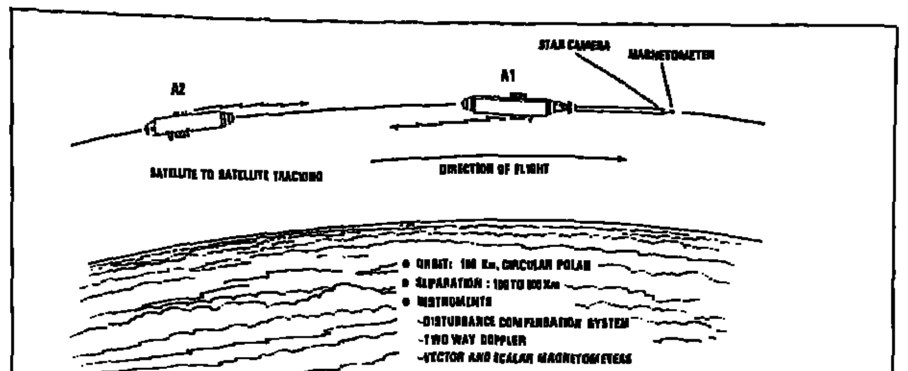


Fig. 1. GRM flight profile. Schematic representation of mission satellite configuration.

Fig. 2. NASA Goddard Space Flight Center (GSFC) global gravity geoid based on a combination of the GSFC GEM 10B earth model and 1° × 1° surface gravity data. Contour interval is 2 m. Longitude is given east from Greenwich.

Introduction

From the very beginning of the artificial satellite era, space platforms have been used to map the gravity and magnetic fields of the earth. In 1958 Vanguard 1 [*O'Keefe et al.*, 1959] and Sputnik 3 were the first satellites to map these geopotential fields. Tables 1 and 2 list the most significant satellites that have been used to study the near-earth gravity and magnetic fields. The major difference between these two groups of satellites (Tables 1 and 2) is that the magnetic field has been recorded directly with flux gate, proton precession, and alkali vapor magnetometers, while the gravity field has been derived indirectly from resolving discrepancies in the satellite's motion. These perturbations in motion were revealed by precisely recording elements of the satellite's position and velocity via optical, radar/laser ranging, or Doppler techniques. With the current field models [*Lerch et al.*, 1981], we have a 500 km horizontal resolution; however, the GRM should provide a 100 km wavelength resolution.

Earth orbiting satellites are advantageous for geopotential field determinations owing to their rapid, global coverage. With magnetic measurements, speed is particularly important since the field changes in time as well as space. These earlier missions have had two unsatisfactory characteristics: They were relatively high (>400 km) and had elliptical orbits. The Geopotential Research Mission will record both the gravity and magnetic fields from a 160 km altitude circular orbit. This project will unify the measurement of these major geopotential fields by recording them simultaneously. We will discuss this planned project and its scientific rationale and present some simulations of the anticipated data set.

To ensure complete global coverage, GRM will consist of two satellites in a 90° ± 0.1° polar orbit of 160 km altitude for 6 months and be separated by up to 600 km (Figure 1). The operation altitude of 160 km was chosen to reconcile the scientific requirements for resolution with the engineering designs for the size of the fuel tanks. These parameters are firm mission requirements and these spacecraft have been designed, for fuel and drag considerations, to fully meet these parameters. Gravity values will be derived form recording the range-rate between the two spacecrafts, while the lead vehicle will project a boom containing scalar and vector magnetometers and the attitude-determining sun sensors and star cameras.

The time of launch of this proposed new mission, if approved, will most likely be 1989–1990.

Scientific Objectives

Because GRM will be launched into a 160 km circular-polar orbit, it will measure both the gravity and magnetic fields of the earth with an accuracy and resolution not as yet obtainable from previous spacecraft. Unlike earlier satellite altimetry missions, GRM will record gravity field data over continental as well as oceanic areas. Having this accurate and detailed data set will allow us to study many regional scientific problems of the solid earth.

Both gravity and magnetic reference field models (such as in Figures 2 and 3) will be greatly improved by the data from GRM. A more detailed gravity field model will allow additional refinements to be made for the determination of other satellite orbits (for example, of altimeter bearing satellites). Previously completed altimetry missions (e.g., Seasat and GEOS 3) could have their orbital parameters redetermined yielding a much more accurate estimation of sea-surface height. Together with the vastly improved geoid, this redetermination will render the sea-surface topography during those previous missions in unprecedented detail.

Further improvements to the global geodetic datum will also be achieved. Since all geophysical anomaly fields are produced by removing the theoretical or reference field from the observed data, any significant improvement will result in refined anomaly mapping, particularly in the area of crustal studies.

Enhancement of the intermediate wavelength features of the gravity field models (100 km ≤ λ ≤ 1000 km) are important for our understanding of the mass variation in the upper mantle. These mass anomalies are probably related to the forces driving the lithospheric plates as well as indicating the physi-

Article *(cont. on p. 610)*

TABLE 1. Orbital Characteristics of Significant Satellites Used for Modeling the Earth's Gravity Field

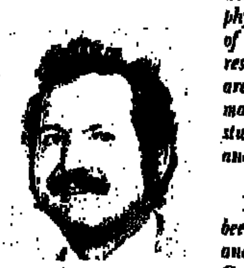
Satellite	Inclination, degrees	Altitude Range, km	Launch Date	Instrument	Approximate Accuracy
Agena Rocket Body	69.91	912–926	1964	O	3–4"
Anna-1B	50.1	1076–1182	Oct. 1962	O	3–4"
				RR	5 cm/s
BE-B	79.69	876–1075	1964	L, RR,	2 m, 5 cm/s
				O	3–4"
BE-C	41.19	936–1322	1965	L, RR, O	
Courier-1B	28.31	971–1211	1960	O	
DI-C	39.97	572–1353	1967	O	
DI-D	39.46	598–1890	1967	L, O	
Echo-1 Rocket Body	47.21	1494–1682	1960	O	3–4"
GEOS-1	59.4	1116–2277	Nov. 6, 1965	L, RR, O	1–2 m, 5 cm/s 2"
GEOS-2	105.8	671–976	Jan. 11, 1968	L, R, RR, O	1–2 m, 1 m 5 cm/s 1–2"
GEOS-3	115.0	821–854	April 9, 1975	L	25 cm
GRS	49.76	428–1294	1963	O	3–4"
INJUN	66.82	880–996	1961	O	
Landsat-1	98.8	898–911	July 23, 1972	RR	5 cm/sec
Lageos	109.8	5838–5945	May 4, 1976	L	5 cm
Midas-4	95.83	3505–3729	1961	O	3–4"
OGO-2	87	413–1510	Oct. 1965	O	3–4"
OSCAR-7	89.7	867–1199	1966	O	3–4"
OVI-2	144.27	1786–2092	1965	O	3–4"
SECOR-5	69.2	1135–2419	Aug. 10, 1965	O	3–4"
Starlette	49.8	806–1108	Feb. 6, 1975	L	5 cm
PEOLE-1	15.0	395–465	Dec. 12, 1970	L, M	1 m 20"

M, Minitrack; L, Laser Ranging; R, Radar Range; RR, Doppler; and O, Optical.

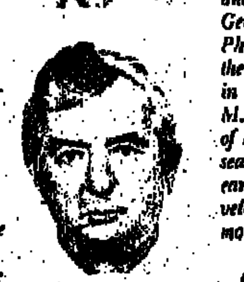
TABLE 2. Satellites That Have Measured the Near-Earth Geomagnetic Field

Satellite	Inclination, degrees	Altitude Range, km	Launch Dates	Instrument	Approximate Accuracy, nT
Sputnik 3	65	440–600	May–June 1958	Fluxgate	100
Vanguard 3	33	510–3750	Sept.–Dec. 1959	Proton	10
1963–38C	Polar	1100	Sept. 1963–Jan. 1974	Fluxgate (1 axis)	30–35
Cosmos 26	49	270–403	March 1964	Proton	Unknown
Cosmos 49	50	261–488	Oct.–Nov. 1964	Proton	22
1964–83C	90	1040–1089	Dec. 1964–June 1965	Rubidium	22
OGO-2	87	413–1510	Oct. 1965–Sept. 1967	Rubidium	6
OGO-4	86	412–908	July 1967–Jan. 1969	Rubidium	6
OGO-6	82	397–1098	June 1969–July 1971	Rubidium	6
Cosmos 321	72	270–403	Jan.–March 1970	Cesium	Unknown
Azur	103	384–3145	Nov. 1969–June 1970	Fluxgate (2 axis)	Unknown
Triad	Polar	750–832	Sept. 1972–present	Fluxgate	Unknown
Magsat	Polar	352–561	Oct. 1979–June 1980	Fluxgate	6
				Cesium	2

From *Langel* [1980].



Patrick T. Taylor *received a B.S. in geology (Michigan State) and an M.S. and Ph.D. in geophysics (Penn State and Stanford). At the Geophysics Branch at GSFC he is currently involved with the geologic interpretation of satellite geophysical data.*



T. Keating *graduated from Georgia Tech (B.E.E., 1956) and Catholic University (M.S.E.E. 1964). He has had additional graduate work in modern communications at George Washington University (1978 to 1981). He is the study manager for the GRM and works in the Advanced Mission Analysis Office of GSFC.*

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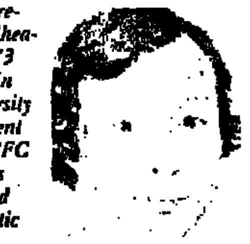
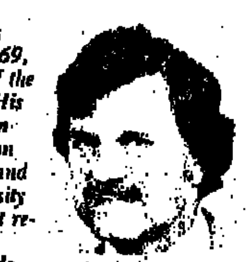
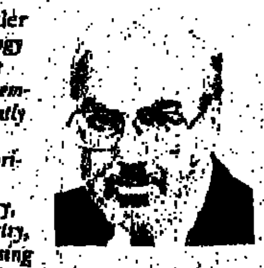


Robert A. Langel *received his B.S. from Wheaton College and in 1973 was awarded a Ph.D. in physics from the University of Maryland. His current research interests at GSFC are modeling the earth's main magnetic field and studying crustal magnetic anomalies.*



David E. Smith *has been at GSFC since 1969, and is presently head of the Geodynamics Branch. His Ph.D. was granted from the University of London in 1966 after a B.Sc. and M.Sc. from the University of Durham. His current research interests involve earth rotation and the development of space techniques for measuring plate motions and crustal deformation.*



Charles C. Schnetzler *received a B.S. in geology from Kansas University and his Ph.D. in geochemistry from MIT. Currently head of the Geophysics Branch at GSFC, his primary research interests have been geochronology, trace element geochemistry, planetology, remote sensing and more recently, the interpretation of satellite-derived magnetic anomalies.*

Article *(cont. from p. 609)*

cal characteristics of material in the asthenosphere. Shorter wavelength features (λ < 100 km) are indicative of the relative density, nature, and physical state of the lithosphere and crust. *Marsh and Marsh* [1976] and *Lambeck* [1976] have correlated patterns in the global free-air gravity anomaly field with geological features, convection, and density inhomogeneities.

Magnetic field data obtained from GRM will enable comparable insights into our understanding of the solid earth. Both the vector and scalar magnetic field measurements will be used to further refine the geomagnetic reference field models, which are being continually improved (Figure 3). When the dense and precise GRM values are used alone or combined with the earlier reference field [*Langel et al.*, 1980] we will sense the time-varying magnetic field as never before. The time terms derived from this comparison can be applied to the commonly used International Geomagnetic Reference Field [*Peddie*, 1981] for the practical applications of magnetic survey reductions and compilation of areally contiguous magnetic charts. In maintaining global reference field models it is necessary to record the magnetic field periodically in order to detect the unsteady temporal field variations.

Beyond the mechanics of refining the reference fields for chart reduction and navigational purposes, a great deal can be learned about the earth's interior from these studies. The energy distribution in the lower harmonics in the magnetic field are important parameters in studies of the earth's core [*Benton et al.*, 1979].

Shorter wavelength features ($\lambda \leq$ 500 km) of the magnetic field, the so-called anomaly field, have been interpreted to be the result of: (1) intracrustal contrasts in magnetization [*Regan and Marsh*, 1982; *Mayhew et al.*, 1982]; (2) variations in the thickness of the crustal magnetized layer by Curie isotherm depth [*Mayhew*, 1982] or crustal thickness [*Schnetzler and Allenby*, 1983]; and (3) surface geological/tectonic features [*Frey*, 1982].

With the greater increase in resolution of the magnetic anomaly field from the GRM it may be possible to derive a geological/tectonic framework for economic evaluation as well as solve significant plate-tectonic problems.

The gravity and magnetic field data sets obtained by GRM will be complementary and supplementary. Both will furnish information about the lithosphere, its bulk composition, physical properties, and state. But gravity data will be primarily sensitive to mantle inhomogeneities and processes while magnetic measurements will mainly reflect the nature of the core. These geophysical potential field results will truly enable us to study the entire earth. These data sets will be useful to the studies of the smaller scale ($\lambda \approx$ 100 km) global-crustal features (such as foldbelts, rifts, structural basins, and oceanic fracture zones and seamounts.)

Mission Profile

Two satellites (Figure 1) designated A1 and A2 will be launched by the shuttle into a polar (90° ± 0.1°) orbit. The shuttle will launch the satellites at 275 km altitude, and they will self-deboost to a lower operating altitude of 160 km to begin a 6-month scientific mission. The spacecraft will orbit the earth with a period of about 88.5 minutes, providing approximately 16.3 orbits per day. Precision tracking of both spacecraft will be determined by the Defense Mapping Agency satellite tracking network.

Magnetometers, star cameras, and sun sensors will be located on an aluminum boom projected about 4 m from the A1 spacecraft (Figure 1). This lead satellite will weigh about 2800 kg, which is 200 kg greater than A2.

Gravity values will be derived by measuring the Doppler or range rate between the two satellites. The Satellite-to-Satellite Doppler Tracking System, which consists of ultrastable oscillators, multiplers, and horn antennas (the latter being mounted above and below each spacecraft (Figure 1)) will be able to detect small changes in the distance by measuring the Doppler frequency shift of the continuous wave of the 91 and 42 GHz signals.

These continuous wave signals are transmitted between the A1 and the A2 spacecraft. The Doppler-shifted signals will be compared to on-board reference frequencies, and consequently the variation in the range between the spacecraft will be determined. The range variation is continually time-sampled. The time-sampled range variation provides a measure of the relative velocity between the spacecraft to a sensitivity of 10^{-6} m s^{-1}.

Separating gravity field perturbations on the satellite orbits from external influences (such as atmospheric drag, solar radiation pressure, and solar and lunar gravity) is accomplished by the Disturbance Compensation System [*Ray*, 1983]. This system consists of a 14 cm diameter ball (called the "proof mass") within a 16 cm diameter spherical cavity. The spherical cavity is also an electrical capacitor. The position of the proof mass in the cavity is determined by the capacity relative to each axis. When the proof mass is off center, the resultant imbalance on the capacity is resolved into vector thrust commands to the appropriate thrusters of the propulsion system. The resultant movement of the spacecraft recenters the proof mass within the cavity. Since the spacecraft shields the proof mass from all perturbing surface forces, the mass responds only to variations in the gravity field. The two spacecraft positioned by the proof mass's response to gravity are themselves the instruments for detecting the gravity field. Interaction between the spacecraft and the earth's electromagnetic field could result in small, torque-like forces. These relatively weak electromagnetic field forces are countered by the reaction-wheel torque, thus eliminating any secular effects.

Distance between the spacecraft may be varied up to 600 km in order to more accurately measure specific harmonics of the gravity-field spectrum.

According to the mission plan, the maximum distance between profile crossings of the equator will be about 7 km. The design goals for the earth's gravity field analysis are a 1 milliGal accuracy in field measurement with a 5 cm geoid height resolution; both will be resolved to less than a degree (100 km). Magnetic field determination should have the same spatial resolution with scalar field accuracy of 2 nT and vector components to 20 arc seconds. All stated accuracies are at the 1 sigma level.

Data Simulation

In an effort to assess the improvements to be realized in the gravity and magnetic fields from the GRM, simulations were conducted for recovery of both fields using the mission's nominal orbit altitude and inclination. These studies provide an estimate of the geological and geophysical interpretations which can be derived from the GRM's data [see *Douglas et al.*, 1980; *Jekeli and Rapp*, 1980; *Piscane and Yionoulis*, 1980; *Colombo*, 1981].

Magnetic anomaly field simulations were aided by the availability of a digitized version of the new Composite Magnetic Anomaly Map of the United States [*Zietz et al.*, 1982], obtained from the Phoenix Corporation by Goddard Space Flight Center under a proprietary contract. *Schnetzler et al.* [1983] determined that there was a long wavelength component (~ 5000 km) in this U.S. magnetic anomaly map. Therefore before extrapolating these data for higher altitudes ("upward-continuing" the data), a long-wavelength trend surface was removed by applying a general, two-dimensional polynomial surface (with ninth-order terms in longitude and fourth-order terms in latitude with cross terms; this is equivalent to 45 degrees of freedom). Theoretically, we should be able to apply the long-wavelength (low pass) filter to the data set either before or after the upward continuation. In practice, however, if this filter were applied to the data after continuation, the long-wavelength components would completely dominate the field and the shorter wavelength features would be harder to detect. The magnetic anomaly data points were selected at 0.2° intervals and upward-continued to 160 km altitude by a mathematical algorithm of *Bhattacharyya* [1977], modified by J. Phillips of the U.S. Geological Survey. At this altitude the field points were plotted at a 0.4° grid interval and contoured (Figure 4). Profiles were taken through this data and one is presented in Figure 5.

When we compare the upward-continued field (Figure 4) with a recent U.S. Magsat anomaly map at 320 km altitude (Figure 6) [*Mayhew and Galliher*, 1982], we can, not surprisingly, note the greater resolution of the lower orbiting satellite. Theoretical-modeling studies, however, indicate that an even greater resolution of the magnetic anomaly field should be apparent. Differences in resolving power between the idealized models and the upward-continued U.S. magnetic anomaly field may be a result of a less than optimum field being removed from the latter. Further efforts are under way to define a more appropriate regional field for the digitized data base for the United States.

For gravity-field simulations, a free-air anomaly map was computed at 160 km altitude from the U.S. Geological Survey data tape (Figure 7) [*U.S. Geological Survey*, 1982] using the same upward-continuation algorithm used with the magnetic field simulation. More efficient computer usage required that the original 4 km spacing between data points be increased to 20 km. Since we were computing the field at an altitude of 8 times this data interval, this was not considered to be a serious problem. These gravity values were plotted at the GRM nominal altitude (160 km) and at the nominal Magsat height (320 km). This comparison was used to suggest the increasing anomaly resolution to be expected from the lower-orbiting GRM.

In an effort to assess the geological significance of the potential field data anticipated from this proposed mission, a simplified tectonic map was superimposed on the magnetic field simulated at 160 km altitude (Figure 8). Since the magnetic measurements were not reduced to the pole, a strict spatial correlation cannot be made.

Conclusions

The proposed GRM would accomplish the task of the satellites listed in Tables 1 and 2. Gravity and magnetic field modeling together with crustal anomaly studies would be the two major geophysical disciplines to benefit from this mission. GRM data would also be relevant to more specialized topics such as earth-core modeling; geoid ocean surface separation; and ocean current investigations.

Engineering studies and data simulations have revealed that the mission goals (gravity held to 2 milliGals, geoid to 10 cm, and magnetic field anomaly map to 1 nT with a 20 arc-second direction reference—all with 100 km resolution) are realistic and should be achievable.

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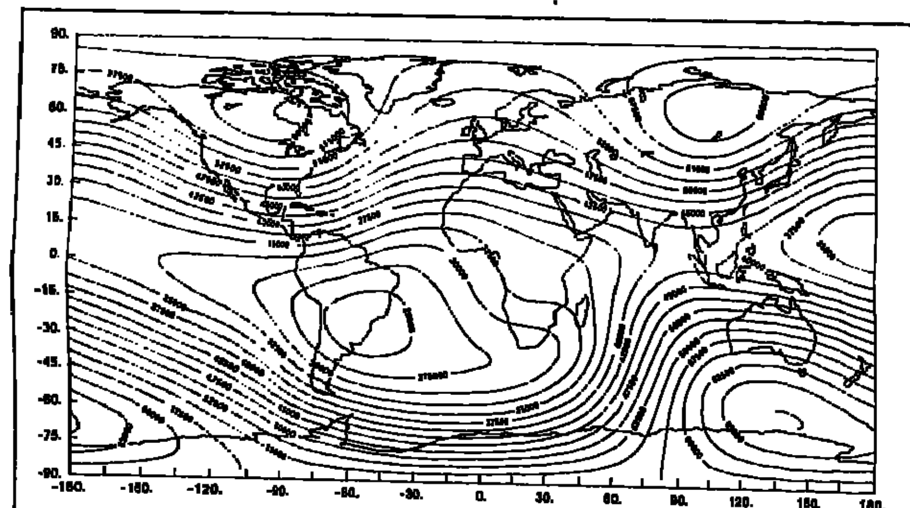

Fig. 3. Magsat-derived total-magnetic field map computed at the earth's surface. Contour interval is 2500 nT.

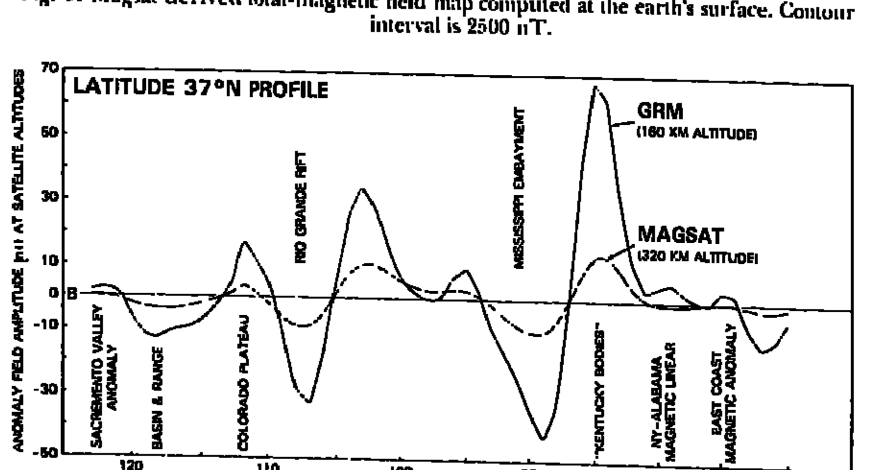

Fig. 5. Magnetic-anomaly field profiles along 37° north latitude. Data from Figures 4 and 6. Prominent tectonic/geophysical features are given for reference.

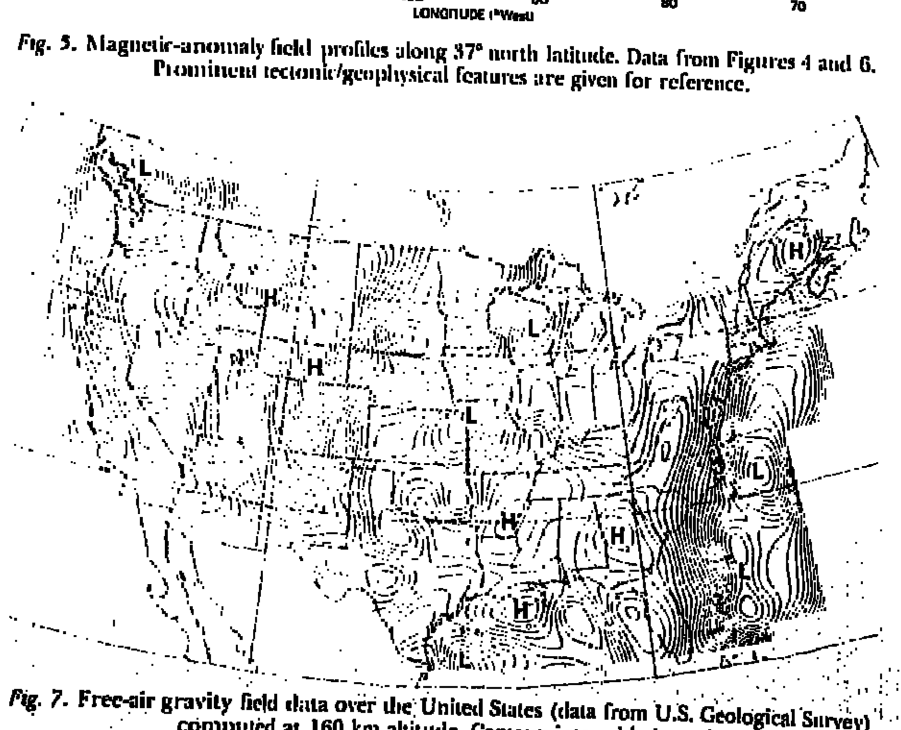

Fig. 7. Free-air gravity field data over the United States (data from U.S. Geological Survey) computed at 160 km altitude. Contour interval is 1 mgal.

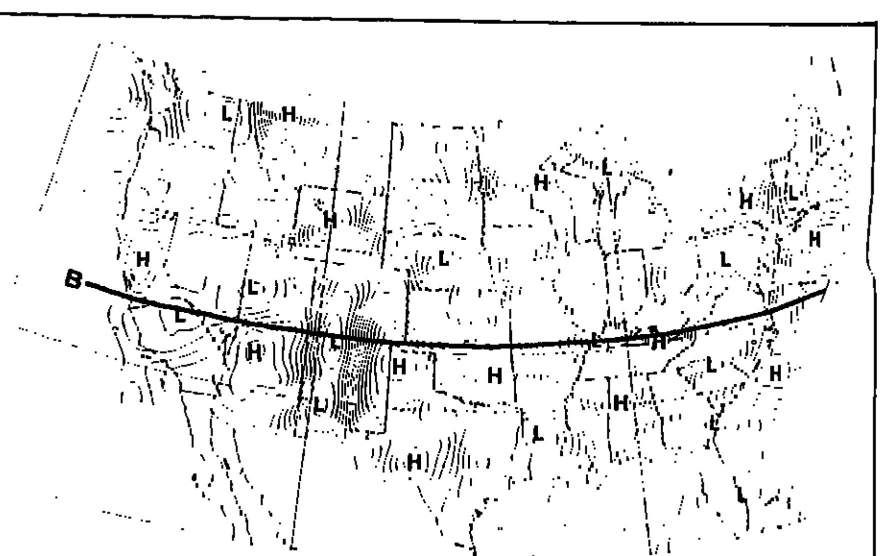

Fig. 4. U.S. Composite Magnetic Anomaly Map continued upward to 160 km altitude. Contour interval is 5 nT.

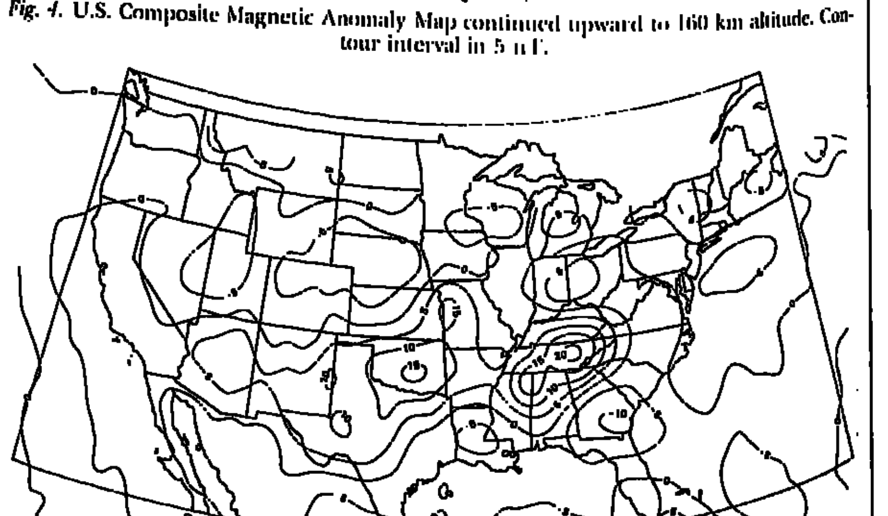

Fig. 6. Magnetic anomaly map of the United States computed at 320 km altitude [from *Mayhew and Galliher*, 1982]. Contour interval is 5 nT.

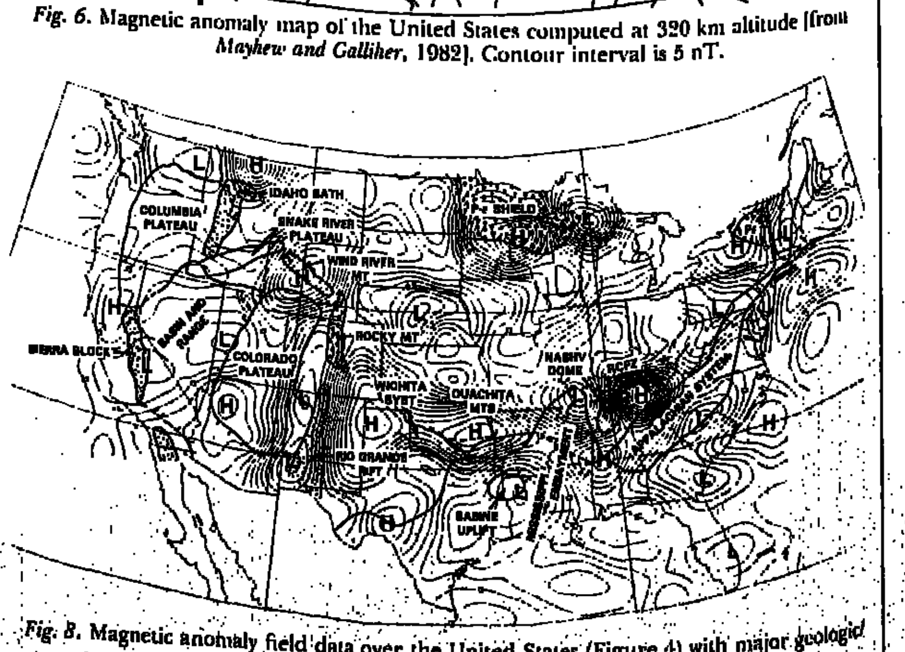

Fig. 8. Magnetic anomaly field data over the United States (Figure 4) with major geologic/tectonic features superimposed (based on *King* [1977]).

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Cover. Simulation of the launching of a Geopotential Research Mission (GRM) satellite from the space shuttle. The GRM mission has been proposed by the National Aeronautics and Space Administration (NASA) for launching by the end of the decade. (See article, this issue.) (Photo courtesy of Patrick T. Taylor, NASA Goddard Space Flight Center, Greenbelt, MD 20771.)

Marine Sulfur Sources

The world's oceans have been known for several years to be a significant source of sulfur in the atmosphere. Current estimates place sulfur from marine sources at about 50% of the atmospheric sulfur attributable to human sources. However, recent work published in *Geophysical Research Letters* (GRL) indicates that estimates need to be refined to account for seasonal variations in the production of marine sulfur and poor understanding of air-sea interchange processes.

Dimethyl sulfide (DMS) represents more than 95% of the volatile sulfur compounds found in the ocean. Joel D. Cline and Timothy S. Bates, in the October issue of GRL, show that production of DMS in the central equatorial Pacific is strongly correlated with chlorophyll "a," a measure of phytoplankton abundance, which is in turn associated with equatorial upwelling. The concentrations of DMS Cline and Bates found from 6°N to 6°S and from 148°W to 170°E (about 2% of the world's ocean surface area) would yield about 1% of the entire annual flux of sulfur from the ocean to the atmosphere.

The findings of Cline and Bates in the equatorial Pacific accord with those of M. O. Andreae and H. Raemdonck (*Science*, August 19, 1983), who sampled DMS there and elsewhere in the Pacific and Atlantic oceans. However, since DMS in the oceans is correlated with biological production and possibly phytoplankton speciation, its contribution to atmospheric sulfur will likely vary with changes in the seasons and geographical areas.

"Only a small fraction of the world oceans have been investigated and little progress has been made on the seasonal variations at high latitudes," say Cline and Bates. In addition, "Oceanic fluxes . . . are currently based on a large number of assumptions, chief among them . . . the validity of the stagnant film boundary layer model as it applies to a reactive species such as DMS."

The work of Cline and Bates was supported by the federal government's interagency National Acid Precipitation Assessment Program, part of whose program is measuring the relative contributions of natural and anthropogenic sources of atmospheric sulfur.

This summary of a paper in the current Geophysical Research Letters was contributed by Joel D. Cline.

Venusian Lightning

Laboratory simulations by William J. Borucki and coworkers (*Geophysical Research Letters*, October 1983) indicate that the inability of satellite instruments to detect optical pulses of Venusian lightning is due to the weakness of the signal rather than its spectral characteristics.

Evidence of lightning activity in the Venusian atmosphere has been obtained by instrumentation aboard the Pioneer Venus Orbiter (PVO) and Venera 9, 11, and 12 spacecraft. However, a search by Borucki and coworkers for optical pulses radiated by Venusian lightning was unsuccessful. The search used the star sensor aboard the PVO to cover the geographical region from 70°N to 50°S latitude and from 240° to 60° longitude (IAU coordinates). B. Vonnegut and R. E. Orville have suggested that Venusian lightning might emit very little radiation at wavelengths greater than 480 nm. This would reduce the possibility of detecting and mapping lightning activity using many solid-state sensors because these sensors are most sensitive in the red rather than in the blue spectral region.

To test the hypothesis of spectral limitation, the lightning facility at the NASA Langley Research Center was used to produce an electrical discharge across a 5-mm gap in a special gas mixture to simulate lightning in the Venusian atmosphere. Both aluminum and tantalum electrodes were used to assess the contribution of electrode radiation.

A comparison of the air spectrum from the capacitor discharge with that obtained by Orville and L. E. Salanave for terrestrial lightning showed that all the prominent lines in the terrestrial spectrum are also found in the spectrum from the capacitor discharge. Because the same lines appear with approximately the same relative intensity in both spectra, the capacitor discharge produces a useful simulation of terrestrial lightning; nevertheless, such a simulation must be regarded as purely exploratory.

A comparison of the spectra obtained from the simulation with those obtained by Orville and Salanave for terrestrial lightning showed that (1) nitrogen lines are dominant in the terrestrial spectrum, but are not found in the simulated Venusian spectrum; (2) carbon lines are prominent in the simulated Venusian spectrum, but do not appear in the terrestrial spectrum; (3) oxygen lines and the hydrogen-Hα line are present in both spectra.

A comparison of simulated and predicted spectra shows that most of the lines predicted are present in the experimental spectrum. A comparison of the predicted radiant fluxes from line radiation in the blue region (i.e., 350–600 nm) and the red region (600–900 nm) shows that the flux in the red region is approximately 5 times larger than that in the blue region.

It is fortunate that Venusian lightning is expected to radiate strongly in the region of 600 to 900 nm because the in situ measurements by V. I. Moroz et al. of atmospheric transmission, and the radiative transfer calculations by M. A. Williams et al., show that very little radiation at wavelengths shorter than 500 nm will penetrate the Venusian atmosphere and clouds. In particular, lightning observed through the Venusian atmosphere will have a reddish hue. Consequently, the reason the star sensor did not detect the Venusian lightning was not its spectral characteristics; rather, it seems likely that the low flashing rate or the low intensity produced a signal level that was too low to be detected.

This summary of a paper in the current Geophysical Research Letters was contributed by William J. Borucki.

Planetary Instruments

November 30 is the deadline for submitting proposals for the National Aeronautics and Space Administration's (NASA) planetary instrument definition and development program (PIDDP). Proposals arriving after the deadline will be reviewed next year. Formerly called the planetary instrument definition program, PIDDP aims "to define and develop new instruments and instrument components or improved versions of existing instruments so that they may be proposed in response to future announcements of flight opportunities as candidate experiments that would not need further development if selected."

NASA encourages new proposals that focus on support for studies aligned with future mission plans of the Solar System Exploration Division (*Eos*, May 24, 1983, p. 386, and February 15, 1983, p. 65). Among the missions recommended by the Solar System Exploration Committee (SSEC) are the Venus Radar Mapper, the Mars Geoscience/Climatology Orbiter, the Comet Rendezvous/Asteroid Flyby, and Titan Probe/Radar Mapper. Subsequent missions recommended include the Mars Aeronomy Orbiter, the Venus Atmosphere Probe, the Mars Surface Probe, and the Lunar Geoscience Orbiter.

Those studies that are continuations of work already reviewed, accepted, and funded will continue to receive support in fiscal year 1984 at levels previously negotiated, unless the investigator requests a change in scope or an increase in the funding level. However, investigators of all continuing studies should note that fiscal 1984 will be the last year of approval for these ongoing efforts. Completely new proposals will be required for support in fiscal 1985 and beyond.

For additional information, contact Fred Vesculus, Code EL-4 (PIDDP), NASA, Washington, DC 20546.

Geophysicists

Rear Admiral John D. Bossler, a member of the National Oceanic and Atmospheric Administration (NOAA) Corps and secretary of the AGU Geodesy section, is the new director of the National Oceanic and Atmospheric Administration's charting and geodetic services. Bossler was director of NOAA's National Geodetic Survey.

Frank Stehli, dean of geosciences at the University of Oklahoma, has been appointed chairman of the Continental Scientific Drilling Committee of the Board on Earth Sciences, National Research Council.

Recent Ph.D.'s

Eos periodically lists information on recently accepted doctoral dissertations in the disciplines of geophysics. Faculty members are invited to submit the following information, on institution letterhead, above the signature of the faculty advisor or department chairman: the dissertation title, author's name, name of the degree-granting department and institution, and month and year degree was awarded. If possible include the current address and telephone number of the degree recipient (this information will not be published).

The Border Ranges Mafic and Ultramafic Complex: Plutonic Core of an Intraoceanic Volcanic Island Arc, Laurel E. Burns, Dept. of Geophysics, School of Earth Sciences, Stanford Univ., September 1983.

Crustal Shear Velocity Modelling in Nevada: A Study of Broadband Multi-Mode Surface Waves, Kin Yip Chun, Dept. of Geology and Geophysics, Univ. of California, Berkeley, December 1983.

Helium, Neon, Water, and Carbon in Volcanic Rocks and Gases, Robert Joseph Poreda, Graduate Dept. of Scripps Institution of Oceanography, Univ. of California, San Diego, December 1983.

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For further information, call toll free 800-424-2488 or, in the Washington, D. C., area, 462-6903.

POSITIONS WANTED

Physical Chemistry. Ph.D. specialized in Isotopic Geochemical Basic Research would consider challenging opportunity. P.O. Box 018 American Geophysical Union, 2000 Florida Avenue, N.W., Washington, DC 20009.

Geochemist/geologist. Ph.D., 6 years of experience in trace element geochemistry, volcanology, hydrothermal processes, water-rock interaction, with field/lab techniques on land or at sea. Also teaching experience at university level. Seeks Research/Teaching/Industrial position in the Washington, D.C. area. Resume on request. American Geophysical Union, 2000 Florida Avenue, N.W., Box 019, Washington, D.C. 20009.

POSITIONS AVAILABLE

Geochemist/Alfred University. Invites applications for a tenure track position in geology commencing August 1984. We seek candidates with a Ph.D., who have a commitment to undergraduate education, are able to teach a variety of courses in geology which might include geochemistry, mineralogy and petrology, and have a strong interest in working closely with students. Alfred University has an enrollment of approximately 2100 students and is located in a rural setting in western New York state. There are approximately 25 geology majors and the department cooperates in a strong environmental studies program. Excellent analytical and research facilities are available on campus in conjunction with the New York State College of Ceramics which is an integral unit of Alfred University and a Vax 11/780 computer is available. Interviews will be conducted at the G.S.A. meeting in Indianapolis and at Alfred University. Interested candidates should send a resume and three letters of recommendation to Dr. M.W. Webb, Chairman, Division of Physical Sciences, Alfred University, Box 832, Alfred N.Y. 14802. Telephone (607) 871-2208.

Alfred University is an equal employment, affirmative action employer and encourages applications from women and other minorities.

North Carolina State University/Marine Chemist. The Department of Marine, Earth, and Atmospheric Sciences invites applications for a 9 month, tenure track position at the assistant or associate professor level. The candidate must have a Ph.D. and will be expected to interact with various research programs within the department such as: radiochemistry, stable isotope and trace metal geochemistry, sedimentology, ocean circulation, air-sea interaction, and biological oceanography. Responsibilities include conducting a viable research program as well as teaching and advising graduate students. Applicants should forward a resume and the names of at least three references to: Dr. David J. DeMaster, Chairman, Search Committee, P.O. Box 5068, North Carolina State University, Raleigh, NC 27650. Application material should be sent by November 30, 1983.

North Carolina State University is an equal opportunity/affirmative action employer.

University of Nevada/Isotope Laboratory Assistant. Position opening in the Stable Isotope/Radiocarbon Age Dating Laboratory of the Water Resources Center for an assistant whose duties will include sample preparation; operation and maintenance of a mass spectrometer and a liquid scintillation counter; and general laboratory operations. Requires B.S. in Geology or Chemistry and experience in laboratory procedures listed above; glass blowing skill is highly desirable. Position located in Las Vegas, Nevada. Salary commensurate with qualifications. Send resume and letter of application, postmarked by Oct. 31, 1983, to: Personnel Dept., Desert Research Institute, University of Nevada System, P.O. Box 60220, Reno, Nevada 89506.

An Affirmative Action/Equal Opportunity Employer.

University of Wisconsin-Parkside/Tenure-track Position. The Geology Program at the University of Wisconsin-Parkside invites applications for a tenure-track position at the assistant-professor level to begin in August 1984. The successful applicant will be expected to teach undergraduate courses in one or more of the following areas: hydrogeology, low temperature geochemistry, environmental geology; carry out a productive research program in his/her specialty; and share the teaching load in introductory geology courses. The Ph.D. or equivalent is required. Submit a resume, transcripts, 3 letters of reference, and a statement of research and teaching interests by January 31, 1984 to:

Professor Gerald A. Fowler
Geology Program
University of Wisconsin-Parkside
Box No. 2000
Kenosha, Wisconsin 53141

We will interview at the G.S.A. meeting in Indianapolis.

The University of Wisconsin-Parkside is an affirmative action/equal-opportunity employer.

Atmospheric Dynamics and Planetary Physics/The Johns Hopkins University. The Department of Earth and Planetary Sciences intends to make a tenure-track faculty appointment in each of these areas, one in July 1984 and the other in July 1985. The Atmospheric Dynamics post will be at the Assistant Professor level; applicants should have a demonstrated capacity for innovative research with, preferably, post-doctoral experience. The appointment in Planetary Physics will be made at a level commensurate with the attainments of the successful candidate; for appointment as full professor, a high international reputation for research accomplishments is expected. Women and minority candidates are especially encouraged to apply.

It is expected that the appointees will develop programs in teaching and research that will complement the activities of the present groups in geophysical fluid dynamics and geophysics, whose research interests include turbulence, waves, air-sea interactions, stratified flow dynamics, convection, mesoscale meteorology, dynamics of the earth's interior, and volcanology. The appointee in planetary physics will be encouraged to interact strongly with scientists at the Space Telescope Science Institute, which is on campus. The University is a member of the University Corporation for Atmospheric Research.

Applications should include a curriculum vitae, copies of one or two recent publications and the names of at least three referees. They should be sent by January 15, 1984 to Professor O.M. Phillips, Chairman, Search Committee, Department of Earth and Planetary Sciences, The Johns Hopkins University, Baltimore, Maryland 21218.

The Johns Hopkins University is an Equal Opportunity Employer.

NASA NSSDC/ACQUISITION SCIENTISTS

Sigma Data Services Corp. a M/A-COM Company, as contractor operating the National Space Science Data Center (NSSDC) at NASA/GSFC, has immediate openings for scientists in the following disciplines:

—Astronomy/Solar Astronomy/Astrophysics (especially X-ray)
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—Lunar/Planetary Geology/Planetology
—Magnetospheric Physics

M.S. required, PhD preferred. Candidates should have experience in analysis of data from spacecraft experiments in their subject area. Working knowledge of FORTRAN is required. Incumbents will serve as acquisition agents for data archived at NSSDC, interface with investigators, and engage in data synthesis efforts, and the generation of data catalogs. Research opportunities available. Send resumes to Dr. H. K. Hills, Sigma Data Services Corp., NASA/GSFC Code 601, Greenbelt, Md. 20771 or call (301) 344-8105

Deputy Department Head/Texas A&M University. The Department of Oceanography in the College of Geosciences at Texas A&M University is seeking a deputy department head to assist in the academic and administrative functions in the Department. Duties will involve 75 percent administration and 25 percent research or teaching on a 12-month appointment basis. This is a tenure track position and will be filled at an academic level commensurate with the experience of the applicant. Applicant must have demonstrated administrative ability, an established record in research and an interest in teaching at both undergraduate and graduate levels of Oceanography. Closing date for applications is 1 November 1983. Effective date of this appointment will be 1 January 1984.

TAMU is an equal employment/affirmative action employer.

University of Alaska/Exploration Geophysicist—Seismic Stratigrapher. Applications are invited for a tenure-track teaching/research position in the Geology/Geophysics Program of the College of Environmental Sciences. Prime responsibilities will be to teach graduate and some undergraduate courses in the use of state-of-the-art techniques in petroleum exploration geophysics. The successful applicant will also develop an innovative research program to complement our growing petroleum geology curriculum. Doctorate is required. Industrial experience in hydrocarbon exploration and, in particular, the use of seismic reflection data to interpret stratigraphy and facies is desirable. The nine-month faculty position is open starting in January 1984. Rank and salary commensurate with qualifications and experience. Resume and at least three references should be submitted to Dr. Juan G. Roederer, Director, Division of Geosciences, University of Alaska, Fairbanks, Alaska 99701. Applications will be accepted until December 15, 1983 or until position is filled.

Your application for employment with the University of Alaska may be subject to Public Disclosure if you are selected as a finalist.

The University of Alaska is an EO/AA employer and educational institution.

National Center for Atmospheric Research/Visitor Applicants. At the High Altitude Observatory, Visitor Appointments are available for new and established Ph.D.'s for up to one year periods to carry out research in solar physics, solar-terrestrial physics, and related subjects. Applicants should provide a curriculum vitae including education, work experience, publications, the names of three scientists familiar with their work, and a statement of their research plans. Applications must be received by January 15, 1984, and they should be sent to: HAO Visitor Committee, High Altitude Observatory, National Center for Atmospheric Research, P.O. Box 3000, Boulder, Colorado 80307.

NCAR is an Equal Opportunity/Affirmative Action Employer.

Postdoctoral Position. Available for the experimental study of the entrainment, deposition, and transport of sediments in lakes and oceans. The research will be primarily in the laboratory but will also involve some field work. Competence in experimental fluid mechanics and interest in environmental problems is necessary. The position will remain open until filled. Applicants should send resume and names of three references to:

Professor Wilbert Lick
Department of Mechanical & Environmental Engineering
University of California
Santa Barbara, CA 93106

An Equal Opportunity/Affirmative Action Employer.

North Dakota State Water Commission/Geohydrologist. To work in aquifer evaluation and management. Bachelor's degree with two years experience or masters degree with experience in quantitative techniques required. Background in watershed modeling, soil physics or unsaturated flow processes desired. Salary range $1555-$2278 per month. Send resume to:

North Dakota State Water Commission
Hydrology Division
900 East Boulevard
Bismarck, North Dakota 58505

North Dakota State Water Commission is an equal opportunity/affirmative action employer.

Louisiana State University/Chas. T. McCord, Jr. Endowed Professorship in Hydrocarbon Exploration: The Geology Department is seeking an internationally recognized leader in some research specialty critical to the search for oil and gas to fill the Chas. T. McCord, Jr. Endowed Professorship. Applicants are expected to maintain scholarly research in their area of specialty. Rank at Full Professor level with salary competitive with endowed professorships at other major research universities. For consideration send resume, three letters of reference, and a description of future research programs to Lyle McGinnis, Faculty Search, Department of Geology, Louisiana State University, Baton Rouge, LA 70803–4101. Search will remain open until position is filled.

LOUISIANA STATE UNIVERSITY IS AN AFFIRMATIVE ACTION/EQUAL OPPORTUNITY EMPLOYER.

The College of William and Mary/Physics Faculty Position. William and Mary expects to have a tenure-track opening at the assistant-professor level for August, 1984. Preference will be given to applicants in the fields of theoretical plasma physics (including computer simulation), nonlinear mechanics, or statistical mechanics. The physics department currently consists of 22 faculty, 7 postdoctoral research associates, and 40 Ph.D. candidate graduate students. Plasma physics funding is currently from NASA and the Department of Energy. Please send vitae and list of three references to: Chairman, Search Committee, Physics Department, College of William and Mary, Williamsburg, Virginia 23185.

William and Mary is an affirmative-action, equal-opportunity employer; women and minority applicants are encouraged to apply.

University of California/Faculty Appointments. The Department of Geology and Geophysics at the University of California, Berkeley, CA. 94720, pending budgetary approval, expects to make two faculty appointments effective Fall 1984, one at the junior level and one at the senior level. Applicants must be interested in pursuing a vigorous research program and in teaching both undergraduate and graduate students. The preferred areas of specialization are sedimentary petrology and sedimentology, stratigraphy and petroleum geology, regional tectonics, geochemistry, economic geology, and metamorphic geology. Applications, including the names of references, should be sent to the Chairman at the above address by January 15, 1984.

The University of California is an Equal Opportunity/Affirmative Action Employer.

Marine Research Specialist V/University of Rhode Island. Immediate opening for a computer specialist/programmer with experience in VAX/VMS, FORTRAN and Assembly languages. PRIME/PRIMOS and interactive graphics experience is also desirable. Will be responsible for program development related to processing and display of data from SEABEAM and seismic reflection systems used in mopping sea floor. Duties also include operation and maintenance of sophisticated shipboard geophysical equipment, with 3 months at sea with equipment. Working knowledge of electronics and acoustics beneficial. Master's or Bachelor's Degree with equivalent experience, in Computer Science, Physical Science, or Engineering. Salary range: $22,432 to $28,318 plus sea pay. Submit resume by November 1, 1983 to: Dr. Robert S. Detrick, Marine Research Specialist V Position, UNIVERSITY OF RHODE ISLAND, P. O. Box 357, Kingston, R.I. 02881–0357.

An AA/EOE M/F.

Meteorologist/The City College of The City University of New York. The Department of Earth and Planetary Sciences invites applications for an anticipated opening in meteorology. The appointment will start September, 1984. Applicants should have completed the Ph.D. by the time of appointment and have a strong background in synoptic meteorology and computer applications. In addition, the individual should have an interest in atmospheric chemistry or pollution as applied to urban areas, or physical oceanography. The person hired will be required to teach courses in meteorology, and possibly physical oceanography as well as develop and maintain an active research program. Participation in the C.U.N.Y. Ph.D. Program in Earth and Environmental Sciences is anticipated. Rank and salary will be commensurate with experience. Send resume, transcripts and three letters of reference by November 30, 1983 to Professor Dennis Weiss, Chairman, Department of Earth and Planetary Sciences, the City College, 138 Street and Convent Avenue, New York, N.Y. 10031.

The City College of the City University of New York is an equal opportunity affirmative action employer.

Department of Geosciences/University of Houston. The Department of Geosciences is interested in having applications for tenure track positions in the following areas: (1) Geophysics—seismology, exploration, data processing (2) Petrology—sandstones and metamorphic (3) Geochemistry—diagenesis. Salary and rank commensurate with experience. If interested, please send:

(1) A curriculum vitae
(2) A brief statement of teaching and research interests
(3) Three letters of recommendation to:

Dr. John C. Butler
Department of Geosciences
University of Houston
Houston, Texas 77004

Affirmative-action/equal-opportunity employer.

USDA Agricultural Research Service,

Watershed Erosion Research Unit, Tucson, Arizona . . .

. . . is seeking a Hydrologist or Research Hydraulic Engineer to conduct research in hydrology, erosion and sediment yield, and water quality in land resource areas of the southwest. Permanent Federal position. Must be US citizen. Salary range $24,508–$48,553 (commensurate with experience). Interested applicants should contact Dr. Kenneth Renard at 602/629-6037 for additional information and application procedures.

USDA is an Equal Opportunity/Affirmative Action Employer.

The University of Texas at Dallas/Sedimentary Geology. The Geosciences Program at the University of Texas at Dallas is seeking two dynamic individuals for two tenure track positions in the general field of sedimentary geology (carbonates and/or clastics) to begin September 1984. [illegible]

Academic Search # 203
The University of Texas at Dallas
P.O. Box 830688
Richardson, Texas 75083-0688

Applications should be received by February 1, 1984.

The University of Texas at Dallas is an Affirmative Action/Equal Opportunity Employer.

Virginia Polytechnic Institute and State University/Petrologist. The Department of Geological Sciences at Virginia Tech invites applications for a tenure-track junior level faculty appointment in Igneous or Metamorphic Petrology. [illegible]

D. A. Hewitt
Department of Geological Sciences
Virginia Tech
Blacksburg, VA 24061

[illegible]

University of Florida. The Department of Geology invites applications for a tenure-track position [illegible] Dr. N.D. Opdyke; Department of Geology; 1112 GPA; University of Florida; Gainesville, Florida 32611.

The University of Florida is an equal opportunity/affirmative action employer.

University of Missouri-Columbia/Faculty Positions. The University of Missouri-Columbia Department of Geology plans immediate expansion through the addition of three tenure-track faculty positions. [illegible]

Exploration Geophysics
Solid-Earth Geophysics
Hydrogeology
Analytical Structural Geology
Clastic Sedimentology

[illegible]

Tom Freeman, Chairman
Department of Geology
University of Missouri
Columbia, MO 65211

Earth Sciences

The Lamont-Doherty Geological Observatory of Columbia University invites scientists interested in any field of the earth sciences to apply for the following fellowships: Two postdoctoral fellowships, each awarded for a period of one year (extendable to two years in special instances) beginning in September, 1984 with a stipend of $25,000 per annum.

Completed applications are to be returned by January 15, 1984. Application forms may be obtained by writing to the Director, Lamont-Doherty Geological Observatory, Palisades, New York 10964. Award announcements will be made February 28, 1984, or shortly thereafter.

Columbia University is an Affirmative Action/Equal Opportunity Employer.

Geophysicist Tenure-Track Appointment/Department of Geology, University of Toledo. [illegible]

Oregon State University/Biological Oceanographer. [illegible]

Oregon State University is an Equal Opportunity/Affirmative Action Employer.

SEDIMENT CHEMIST/University of Miami. [illegible]

The University of Miami is an Equal Opportunity/Affirmative Action Employer.

Louisiana State University/Tenure-Track Faculty Positions in Geology. The Department of Geology is expanding from 15 to 35 faculty with four positions open Fall 1984 [illegible]

LOUISIANA STATE UNIVERSITY IS AN AFFIRMATIVE ACTION/EQUAL OPPORTUNITY EMPLOYER.

Geophysical Fluid Dynamicist/Aeronautical Research Associates of Princeton, Inc. [illegible]

Instructor/Assistant Professor in Meteorology/January 15, 1984—State University of New York College. [illegible]

Associate Professor/University of Miami. [illegible]

The Department of Earth Sciences/Memorial University of Newfoundland. [illegible]

Clay Mineralogy
Marine Geology
Offshore Engineering Geology
Economic Geology (Mineral Deposits)
Crustal Seismology

[illegible]

Dr. C.R. Barnes, Head
Department of Earth Sciences
Memorial University of Newfoundland
St. John's, Newfoundland, Canada
A1B 3X5
Telephone: (709) 737-8142

Faculty Opening/Department of Geological Sciences, Rutgers University, Newark. [illegible]

Dr. Andreas H. Vassiliou, Chairman
Department of Geological Sciences
Rutgers University
Newark, New Jersey 07102

Rutgers University is an Equal Opportunity/Affirmative Action Employer.

Faculty Position, Water Resources Research Center/University of Arizona. [illegible]

Dr. L. G. Wilson, Chairman
Search Committee
Water Resources Research Center
College of Engineering
University of Arizona
Tucson, Arizona 85721

The University of Arizona is an affirmative action/equal opportunity employer.

Physicist/Math Analyst. Sigma Data Services Corp., an M/A-COM Co., has an immediate opening for a Physicist/Math Analyst. [illegible] Sigma Data Services Corp., NASA/GSFC, Code 601, Greenbelt, Md. 20771 or call (301) 344-8105.

Iowa State University of Science and Technology, Department of Earth Sciences. [illegible]

Dr. Bert E. Nordlie
Department of Earth Sciences
Iowa State University
253 Science I
Ames, Iowa 50011.

Iowa State University is an equal opportunity/affirmative action employer.

Professor of Marine Geophysics Tectonics/Stanford University. [illegible]

Dr. Amos Nur
Department of Geophysics
321 Mitchell Building
Stanford University
Stanford, CA 94305

Stanford University is an equal opportunity employer, and encourages the application of qualified women and minorities.

STUDENT OPPORTUNITIES

GRADUATE STUDENT NASA TRAINEESHIPS

The Florida State University is accepting applications from prospective graduate students for participation in its NASA sponsored Traineeship Program in Oceanographic Remote Sensing Techniques and Physics of Air-Sea Interaction. The stipend for the calendar year is $10,600. [illegible]

Dr. James J. O'Brien
NASA Traineeship Program
Meteorology Annex
The Florida State University
Tallahassee, Florida 32306
(904) 644-4581

Graduate Teaching and Research Assistantships in Marine Environmental Sciences and Coastal Oceanography. [illegible]

AGU

Section Candidates

Eos is carrying biographies and photographs of all candidates for President-elect, General Secretary, and Foreign Secretary of the Union and for President-elect and Secretary of each Section. In addition, statements by the candidates for Union offices and for Section President-elect will appear. The material for the Hydrology Section appears below. The material for the sections of Geodesy, Geomagnetism and Paleomagnetism, and Planetology appeared in the August 30 issue; for the Atmospheric Sciences Section in the September 27 issue; for the Tectonophysics section in the October 11; and for the Seismology Section in the October 18 issue. The slate of candidates for all offices was carried in the June 21 issue.

Hydrology: President-elect

Jacques W. Delleur A member of AGU since 1957; 58 years old, Professor of Hydrology and Hydraulics, Head of the Hydraulic and Systems Engineering Area of the School of Civil Engineering, Acting Director of Water Resources Research Center, Purdue Univ. Major interests: stochastic hydrology and urban hydrology. C.E. & Min. E., Natl. Univ. of Colombia, 1949, MSCE Rensselaer Polytechnic Institute, 1950, D. Eng. Sc. in Hydromechanics, Columbia, 1955. Purdue Univ. faculty since 1955. Member AGU, ASCE, AWRA, AAAS, IAHR, Sigma Xi, Tau Beta Pi. Has been chairman of Fluid Dynamics Committee of Engineering Mechanics Division ASCE and Chairman Task Force on Hydraulics of Bridges ASCE; is Member of Urban Water Resources Research Council ASCE, Member US National Committee for the IASH. 81 journal or conference proceedings publications, 9 published by AGU; 51 technical reports. Coauthor textbook on modeling hydrologic time series. Fellow ASCE. Served as Member of AGU Surface Hydrology Committee since 1975, Chairman of Urban Hydrology Section Executive Committee, coauthor of AGU Water Resources Monograph 7 on Urban Storm-water Hydrology. Convenor and chairman of several symposia in Urban Hydrology and on stochastic hydrology.

Statement

"At present, the Hydrology Section of AGU is under able direction. Should I be elected President of the Section, I intend to continue the efforts for a stronger participation in the Union affairs and to ensure the quality of the publications and scientific programs in our conferences and symposia.

"I would like to work with the editors of our research journal, *Water Resources Research* (WRR), to accelerate the review process and to reduce the time between the submittal of the papers and their publication while maintaining the strong reputation of this journal. At the same time, I would like to provide an outlet for publication of quality original articles in applied hydrology. This would bridge the gap between the research hydrologists who publish in WRR and the large number of practicing hydrologists who at present lack an appropriate publication medium within the section.

"Stronger lines of communication between the president and Section members should be established. This could be accomplished by keeping the members informed about the issues through short articles in *Eos*. Advanced publication of agendas of the meetings of the executive committee would foster the opportunity of the Section members to reflect on their positions on important matters. The members would have a better opportunity to make their views known and to participate in the decision-making process of their Section. Also more opportunities for membership communication could be given at the luncheon meetings.

"Only active committees should exist and they should have well-defined objectives such as organizing scientific sessions, symposia, Chapman conferences, monograph publications, etc. Consideration should be given to the merging of committees with overlapping objectives while encouraging the formation of interdisciplinary groups, or groups exploring new developments.

"Closer interaction with other sections of the Union should be developed, primarily with the Atmospheric Sciences and Ocean Sciences sections. Hydrologists can contribute much to the study of the coupling of atmosphere-land-ocean systems. This interaction could take the form of joint scientific sessions, joint articles in *Eos*, and invited reviews or editorials in WRR.

"Finally, the presidency of the section cannot be considered as an honorary position but rather as a challenge."

Marshall E. Moss A member of AGU since 1963; 43 years old, Chief of Surface Water Branch, U.S. Geological Survey (USGS), Water Resources Division; design of data networks and mixtures of stochastic and deterministic hydrologic models. B.S. in civil engineering, Clemson, 1963; M.S. in civil engineering, Arizona, 1969; Ph.D. in civil engineering, Colorado State, 1975. Hydrologist with USGS from 1963 to present. Member: AGU, ASCE, AAAS, ASA, Sigma Xi. Has served on Hydrology Committee of AMS, as Rapporteur for Network Design for WMO, Co-director of UNESCO Symposium on Droughts in Arid Lands and currently serves as a member of the U.S. Committee for IAHS, Rapporteur for Technical Regulations for WMO Commission for Hydrology, U.S. delegate to WMO Congress, head of U.S. delegation to ISO Technical Committee 113, liquid flow in open channels. 48 publications, 9 published by AGU; recently published by WMO, "Concepts and Techniques in Hydrological Network Design;" by USGS, "Design of Surface-Water Data Networks for Regional Information." Served as Chairman and Member of AGU Tellers Committee, Hydrology Section's Network Design Committee and Horton Award Committee; as member of AGU Horton Medal Committee and Hydrology Section's Surface Water Committee and Stochastic Hydrology Work Group; was convener of Chapman Conference on Design of Hydrologic Data Networks and served as coeditor of the Conference Proceedings published in WRR.

Statement

"The Hydrology Section of AGU plays a somewhat different role than do most other sections of AGU; it is the primary affiliation of many, if not most, of the leaders in the science of hydrology today. There seem to be two reasons for this unique status. First, there has been no other strong society in America dedicated totally to the science of hydrology—there is no Hydrological Society of America comparable to GSA in geology; there is no American Hydrological Society performing for hydrology as AMS does for meteorology. Thus, the Hydrology Section of AGU is where the action is.

"The second reason is the strength of our publication, *Water Resources Research*. Prior to the initiation of WRR, there was no widely distributed publication treating scientific hydrology per se. Articles could be found scattered among engineering journals, conference proceedings, and even in some issues of AGU's *Journal of Geophysical Research*. To be moderately well read in hydrologic literature, one had to diligently search through many journals. However, with the very first issue of WRR, a single source where one could encounter the latest knowledge of all phases of hydrology and of its applications in water-resources management was realized. Thus, AGU's *Water Resources Research* is where the science is.

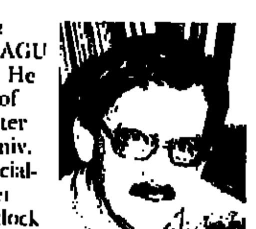
"However, in recent years, each of these two facets of the Hydrology Section have ceased to be wholly true. There are now entities that offer to hydrologists affiliations that approach the level of professional value that once was the Hydrology Section's alone. There are also journals dedicated to hydrology and water resources that have made significant inroads into the publication realm that only a few years ago was almost wholly that of WRR.

"Is this unique status of the Hydrology Section to be maintained? I don't know the long-term answer to this question; however, I don't see any entity to which I want to transfer my primary hydrologic allegiance in the near future. Therefore, I have consented to run for the office of President-elect of the Section to serve what has been and what I hope to help maintain as a very special professional affiliation.

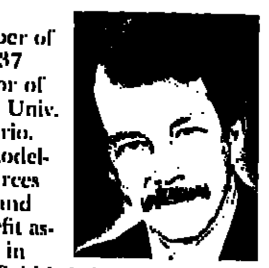
"I see as two primary areas of attention for the Hydrology Section during the next few years the growing volume of pages published by WRR and the move toward "registration" of hydrologists. I feel that we may be approaching the point where the cost and the weight of WRR may begin to reduce its effectiveness as the premier journal in scientific hydrology. This is a condition that must be avoided assiduously by the editors of WRR with assistance from the Section Executive Committee if needed.

"The recently announced American Institute of Hydrology has seemed to have sprung upon us unannounced with its offers of professional registration of hydrologists. I feel that the Executive Committee of the Hydrology Section should make an evaluation of the potential impacts on the membership of the Hydrology Section of registration either by an institute or by a state board, as is more common in other professions. The results of the evaluation should be made available to the Section membership. Monitoring by the Hydrology Section of any registration or certificate process for hydrologists would be a valuable service to its membership."

Hydrology: Secretary



Thomas Maddock III A member of AGU since 1968; age 44. He is now a Professor of Hydrology and Water Resources at the Univ. of Arizona and specializes in ground-water management. Maddock received his undergraduate degree from the Univ. of Houston and his Master's and Ph.D. from Harvard under the Harvard water program. Before leaving to join academia he worked for the U.S. Geological Survey as a member of its Water Resources Division Systems Analysis Group and Groundwater Branch. Maddock was an associate editor of *Water Resource Research*, an editor of the *Journal of Soviet Hydrology* (an AGU publication), and a member of the editorial board of the AGU Water Resources Monograph Series. He is a member of AWRA and has served on numerous committees for AGU, AWRA, and ASCE. He is now the incumbent Secretary of the Hydrology Section.



Edward A. McBean A member of AGU since 1968; 37 years old; Professor of Civil Engineering, Univ. of Waterloo, Ontario. Major interests: modeling of water resources systems (quantity and quality), cost–benefit assessments. B.A.Sc. in civil engineering, British Columbia, 1968, S.M. in 1970, and Ph.D. in 1973, in civil engineering, MIT. Engineer with Acres Consulting Services 1970–1971; project engineer with Meta Systems, Inc., to 1974; research associate, Water Resources and Marine Sciences Center, Cornell Univ., 1974; Univ. of Waterloo since 1974. Edited four books; 52 refereed papers, 3 published by AGU. Member, organizing committees for International Symposium on Risk and Reliability in Water Resources, Waterloo, June 1978; International Association of Water Pollution Research, Toronto, June 1980; and International Symposium on Real-Time Operation of Hydrosystems, Waterloo, June 1981. Appointed representative to Environment Canada Technical Workshop on Modelling, 1976; and Technical Workshop on Streamflow Forecasting, 1983. Reviewer of technical papers for AGU (from 1974), ASCE, WASP, GWMR, CJCE, CWRA, and WPRC. Associate Editor, *Water Resources Research*, 1979 to present.

Meetings

Mantle Processes

A Penrose Conference on "Processes and Products of Multistage Melting and Metasomatism in the Mantle" will be held April 29–May 4, 1984, at Gold Canyon Ranch in central Arizona. Attendance is limited to 80, and the deadline for submitting applications is October 31.

The conference is cosponsored by the Geological Society of America and the U.S. Geological Survey (USGS) to bring together petrologists, experimentalists, geophysicists, geochemists, and other researchers to discuss current research of mantle heterogeneities and the processes that create them. On the agenda is a one-day field trip to the site of the San Carlos, Ariz., mantle xenolith.

Proposed sessions will address the petrology and geochemistry of mantle material that has been modified by multistage events, geochemical evidence of multistate mantle processes from the study of lavas, experimentally determined evidence of the geochemistry of mantle metasomatic fluids, geophysics of melt processes and melt migration, and evolution of chemical heterogeneities in a convecting mantle.

Applications, along with a brief description of topics to be presented at the conference or reasons for attending, should be sent to Jane E. Pike, U.S. Geological Survey, 345 Middlefield Rd., MS 75, Menlo Park, CA 94025.

Lakes, Rivers, Glaciers

The Symposium on Climate and Paleoclimate of Lakes, Rivers, and Glaciers will be held June 4–7, 1984, at Igls, Austria, near Innsbruck. Abstracts of papers to be presented at the meeting should be submitted by December 15 and should deal with any of the following symposium topics related to lakes and rivers or glaciers and ice sheets: present climate, water/ice and energy budgets; recent changes; historical changes; late glacial and post-glacial development; or the physical bases and models for paleoclimate reconstructions.

The International Association of Meteorology and Atmospheric Physics International Commission on Climate is sponsoring the event in cooperation with the International Union for Quaternary Research Paleoclimate Commission, the International Association for Hydrological Sciences Commission on Snow and Ice, and the International Glaciological Society.

Abstracts are to be no longer than one page in length. The papers committee will notify authors of acceptance by February 1, 1984. For more information, contact M. Kuhn, Institut fuer Meteorologie und Geophysik, Schoepfstrasse 41, A-6020 Innsbruck, Austria (telephone 5222-724-3132).

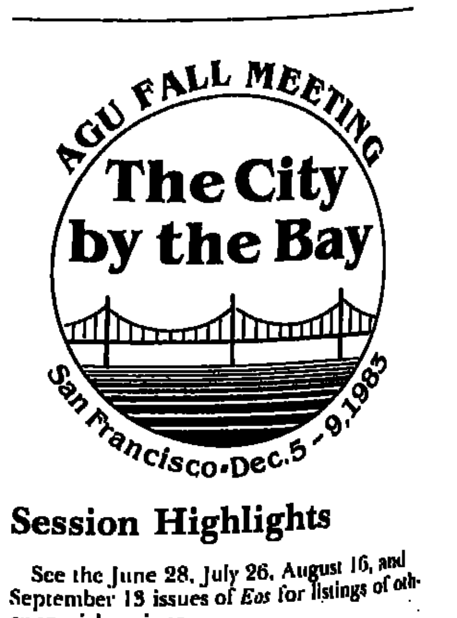
Supporting Members

The following individuals have been added to the list of Supporting Members. The full list was last published with President Van Allen's editorial in *Eos*, September 13, 1983.

Individual Supporting Members

Frank B. Campbell
Herbert Friedman
Vincent E. McKelvey
W. H. Pickering
Lynn R. Sykes

AGU GIFT



Session Highlights

See the June 28, July 26, August 16, and September 13 issues of *Eos* for listings of other special sessions.

Union

The Orinoco and Amazon: Geophysical Considerations *Tuesday A.M., Cathedral Hill, International Room* This session, organized by the Hydrology Section, addresses the implications for climate, ecology, chemistry, and hydrology of development of these major river basins. This all-Union session is followed in the afternoon by a contributed session on the same topic in the Hydrology Section program. **Computers and the Geosciences** *Tuesday P.M., Cathedral Hill, International Room* This is the second all-Union session that addresses themes common to all the geosciences. The first, at the 1983 Spring Meeting, reviewed satellites and the geosciences. Research in all the geosciences requires extensive use of computers. Meteorological research has for many years required access to major computing systems and similar needs are emerging in several other disciplines. This session includes three factors on the use of computers in research and three on computing systems and architecture.

Geophysical and Geochemical Consequences of Nuclear Explosions *Wednesday A.M., Cathedral Hill, International Room* This session, organized by Joseph V. Smith, Thomas J. Ahrens, and the Committee on Public Affairs, addresses various potential geophysical and geochemical consequences of nuclear explosions. The all-Union session is followed in the afternoon by a session specifically relating to atmospheric effects.

Polar Research *Thursday A.M., Cathedral Hill, International Room* Research in the polar regions includes all the geosciences plus biology and is subject to stringent logistical requirements and international political considerations. This session reviews current geophysical research in both polar regions, international scientific planning, and emerging Antarctic political considerations.

History of Geophysics Lectures

Three History of Geophysics Lectures are planned. **The Early History of Whistler Research** will be presented by Owen Storey on Wednesday at 1:30 P.M. in the Holiday Inn (HI) Emerald Room in conjunction with the SPR: Magnetospheric Physics session. **Krakatau 1883: A Classic Geophysical Event** will be presented by Tom Simkin and Richard S. Fiske on Monday at 8:15 A.M. in the Cathedral Hill California Room as part of the Krakatau Centennial session of the Volcanology, Geochemistry, and Petrology section. **Keys to the Revolution in Earth Sciences** will be presented by William Glen on Wednesday at 11:15 A.M. in the Gold Rush B Room (HI) in conjunction with the Geomagnetism and Paleomagnetism Section.

Mineral Physics

The following sessions are organized under the auspices of the Mineral Physics Committee.

Phase Equilibria *Monday A.M., Cathedral Hill (cosponsored by T, V)*
Deformation of Rocks and Minerals *Tuesday A.M., Holiday Inn (cosponsored by T, V)*
Mineral Physics at High Pressures *Wednesday A.M., Holiday Inn (cosponsored by T, V)*
Physics of Magma Transfer *Wednesday P.M., Cathedral Hill (cosponsored by T, V)*
Electrical Properties of the Crust and Mantle *Friday A.M., Holiday Inn (cosponsored by GP, T)*
Physical Chemistry of Minerals *Friday P.M., Holiday Inn (cosponsored by T, V)*

Atmospheric Sciences

Lightning: The Workman Memorial Session *Monday P.M., Cathedral Hill, Eldorado Room* This special poster session on lightning is being held to honor the memory of E. J. Workman, 1899-1982, who was one of the early leaders of modern research on thunderstorms, cloud physics, and atmospheric electricity. Much of the recent progress in lightning and thunderstorms research stems from the work of Workman and his colleagues S. E. Reynolds and I. Langmuir at New Mexico Institute of Mining and Technology over the last 4 decades. Their legacy includes the establishment of Langmuir Laboratory at Socorro, N. Mex.

Workman, a Fellow of AGU, had a broad view of the problems of atmospheric electricity. It is therefore appropriate that the memorial session in his honor be presented in a way that is accessible to the broad community of geophysicists and atmospheric scientists who otherwise might not have a chance to see the latest results in a field to which he contributed so much.

SPR: Magnetospheric Physics

AMPTE Theory and Predictions (Monday A.M. and P.M., Holiday Inn, Crystal Room): The Active Magnetosphere Particle Tracer Explorers will release and monitor quantities of lithium and barium ions in the distant magnetosphere and solar wind so as to elucidate the mechanisms of charged particle access to the magnetosphere and charged particle transport within the magnetosphere. Invited speakers are Tom Krimigis, Dennis Papadopoulos, Christian Dum, Armando Brinca, Ted Speiser, Gerhard Haerendel, Dick Wolf, and Mike Cornwall. An equal number of contributed papers will be distributed among the invited papers. Erwin Schmerling will chair.

Parallel poster sessions (Tuesday A.M., Cathedral Hill, El Dorado Room) on **Auroral and Aubstorm Phenomena** and on **Magnetospheric Currents and Electric Fields** will be held in conjunction with poster sessions on solar, interplanetary, cosmic-ray, and aeronomical topics (SA, SC, SS). About half of the 36 poster papers are magnetospheric (SM). Jean Berchem will chair.

Comparative Planetary Magnetospheres (Tuesday P.M. and Wednesday A.M., Cathedral Hill, Japanese Pavilion) will be featured in two sessions of oral presentations (mostly invited) abouth earth, Jupiter, Saturn, and the solar system as a whole. Invited speakers are Norman Ness, Al Schardt, Tom Armstrong, John Belcher, Bill Kurth, Mike Desch, John Caldwell, Yam Chiu, Ed Stone, and Hannes Alfvén. Dick Wolf and Paul Dusenberry will chair.

The Early History of Whistler Research (Wednesday P.M., Holiday Inn, Emerald Room) will be recounted in a 50-minute address by Owen Storey to open the second half of the meeting. Bob Helliwell will chair.

The physics of **Vehicle Interactions with Space Plasma** (Wednesday P.M. and Thursday A.M., Holiday Inn, Emerald Room) will be featured in two partial sessions of oral contributed papers. Topics include spacecraft charging, spacecraft and antenna wakes, particle-beam effects, and instabilities observed on space-shuttle and rocket flights. Mike Schulz and Dave Gorney will chair.

Geomagnetic Pulsations (Thursday A.M., Holiday Inn, Emerald Room) will be featured in a partial session of two invited and eight contributed papers following completion of the second partial session on Vehicle Interactions with Space Plasma. John Olson (Pc 1) and Gordon Rostoker (Pc 4–5 and Pi 2) are invited speakers. Joseph Kan, who organized the session, will chair.

ISEE-3 Observations of the Distant Magnetotail (Friday A.M. and P.M., Cathedral Hill, Japanese Pavilion) will highlight the final day of the meeting. The two oral sessions will feature new observations made by ISEE-3 at geocentric distances of 80 and 240 earth radii in the tail. Invited speakers are Tycho von Rosenvinge, Bruce Tsurutani, M. A. Coplan, Ed Hones, Fred Scarf, P. W. Daly, and George Gloecker. Eleven contributed papers are interspersed in the program. George Parks and von Rosenvinge will chair.

Parallel poster sessions (Friday A.M., Cathedral Hill, El Dorado Room) will feature **Charged-Particle Populations and Precipitation; Waves and Instabilities in Laboratory and Space Experiments; Auroral Hiss and Kilometric Radiation,** and **Geomagnetic Pulsations** (37 papers in all). Bob Spiro will chair.

Parallel poster sessions (Friday P.M., Cathedral Hill, El Dorado Room) will offer contributions on the **Geomagnetic Tail and Boundary Layer; Ionospheric Rada Results,** and **Waves and Instabilities in the Ionosphere and Magnetosphere** (32 papers in all). Umran Inan will chair.

SPR: Solar & Interplanetary Physics

Solar Wind Interaction with Comets, Venus, and Titan *Thursday A.M., Holiday Inn Crystal Room*

Featured speakers are representatives for all spacecraft going to comet Halley: T. Gombosi (VEGA), H. Oya (Planet A and MST-5), R. Reinhard (Giotto), T. von Rosenvinge (ISEE), and A. Mendis (Theory). Speakers on the topic of the solar wind interaction with Venus are: A. Barnes, P. A. Cloutier, C. T. Russell, and F. L. Scarf. D. E. Jones will discuss the interaction at Titan. The session will be chaired by M. Neugebauer in the morning and S. A. Curtis in the afternoon. Cosponsored by the Planetology Section.

Tectonophysics

Physics of Magma Transfer *Wednesday P.M., Cathedral Hill, International Room* Cosponsored by the Volcanology, Geochemistry, and Petrology and Tectonophysics sections, this symposium will cover the physics of magma transfer from the atomic scale to the scale of mantle plumes. Topics range from experiments to fluid mechanical models of diapirs and the extraction of magma from partially molten systems.

Nominations for the James B. Macelwane Award

Nominations for the prestigious James B. Macelwane Award are still being accepted. Up to three recipients may receive this honor per year to assure that individuals in all areas of geophysics are regularly recognized.

The Macelwane award is given by AGU in "recognition of significant contributions to the geophysical sciences by a young scientist of outstanding ability." Recipients must be less than 36 years old.

Letters of nomination, outlining significant contributions and curriculum vitae should be sent directly to:

J. Freeman Gilbert
IGPP A-025
University of California, San Diego
La Jolla, CA 92093

Deadline for nominations is November 15, 1983.

AGU FALL MEETING
December 5-9, 1983
San Francisco, California

The City by the Bay

Housing Deadline: November 1
Send your housing form directly to the Housing Coordinator, AGU Fall Meeting, S.F. Housing Bureau, P.O. Box 5612, San Francisco, CA 94101.

Preregistration Deadline: November 10
There is still time to preregister. Save time and money! Send your preregistration form to the AGU Fall Meeting, 2000 Florida Ave., N.W., Washington, DC 20009.

Make your Airline Reservation: Call United
Dial the United toll free number 800-521-4041 (In Michigan, 800-482-0243). Give United your AGU Convention Number—4367—to ensure that you receive the AGU Discount Air Fare.

Registration and housing forms, the program summary, and airline information were published in Eos, October 18, 1983. For additional information, contact the AGU Meetings Department at 202-462-6903.

GAP

Separates

To Order: The order number can be found at the end of each abstract; use all digits when ordering. Only papers with order numbers are available from AGU. *Cost:* $3.50 for the first article and $1.00 for each additional article in the same order. Payment must accompany order. Deposit accounts available.

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Exploration Geophysics

0930 Seismic methods
RADIATION IMPEDANCE OF TORSIONALLY VIBRATING SEISMIC SOURCES
Geoffrey A. Dorn (Formerly Engineering Geoscience, University of California, Berkeley; presently Exploration and Production Research, ARCO Oil and Gas Company, P.O. Box 2819, Dallas, TX 75221)

The thickness and shear-wave velocity of a surface layer can theoretically be determined from seismic radiation impedance measurements using a torsional vibrator. These studies also provide physical insight into vibrator-earth interaction.

The radiation impedance of a circular disk vibrating torsionally on an anelastic half-space has resonance peaks with a spacing that is a function of the ratio between baseplate radius and seismic wavelength. At low frequencies the shape of the impedance function is nearly independent of the baseplate flexure, although the magnitude is affected. At high frequencies the impedance depends strongly on the flexibility of the baseplate. The mass of the baseplate introduces an additional resonant effect, the frequency of which is a function of the baseplate mass.

The presence of a surface layer produces an impedance curve which oscillates around the half-space response. The amplitude of the oscillations is a function of the acoustic impedance contrast and depends upon the radiation pattern of the source. The oscillations are caused by reflections within the surface layer and both the period and amplitude of the oscillations are inversely proportional to the layer thickness. The amplitude of the layer resonance decreases rapidly as material damping is increased.

With impedance measurements over a sufficiently broad frequency range (up to about 500 Hz), it may be feasible to use half-space oscillations and the layer resonances to determine the shear velocity and thickness of the layer of material beneath the baseplate.
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